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Site Indexes for Lodgepole Pine, with Corrections for Stand Density:

Instructions for Field Use

by Robert R. Alexander

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SITE INDEXES FOR LODGEPOLE PINE, WITH CORRECTIONS FOR STAND DENSITY; Instructions for Field Use

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Lodgepole pine (Pinus contorta Dougl.) commonly grows in overly dense stands, and crowding restricts the rate of height growth. Site index must, therefore, be adjusted for stand density. Figures 1 and 2, and tables 1 through 7 have been prepared for field use in estimating site index for lodgepole pine. They are applicable to lodgepole pine stands in Colorado, Wyoming, Utah, Idaho, Montana, and eastern Washington and Oregon.[2] Information necessary to understand field application of the site index curves and instructions for their use are presented in this paper. Methodology used to develop the site index curves will be presented in a subsequent paper.

Stand density is expressed as Crown Competition Factor (CCF).[3] CCF compares growing space available to a tree with the space represented by a vertical projection of the average crown area of an open-grown tree of the same stem diameter (Maximum Crown Area, MCA). Because space occupied by a single tree is not easily determined, the comparison is made on a stand basis. CCF may be obtained from the numbers and diameters of trees in a stand, or it may be estimated from measurements of basal area and average diameter.

[2] *This paper is based on a cooperative study planned and undertaken jointly by the Rocky Mountain, Intermountain, and Pacific Northwest Forest and Range Experiment Stations. David Tackle (INT) and Walter G. Dahms (PNW) collected the field data in their respective areas.*

[3] *Krajicek, John E., Brinkman, Kenneth A., and Gingrich, Samuel F. Crown competition factor, a measure of density. Forest Sci. 7: 35-42. 1961.*

Site index is expressed as the average height of dominant trees in pure, even-aged stands at age 100 years. For stands where the CCF is 125 or less, height growth is unaffected by density. For stands where the CCF is greater than 125, height growth is reduced as density increases, and the reduction in height growth at any level of CCF above 125 becomes greater as site quality improves.

Site index can be estimated from tables 1 through 5 for all combinations of height, age, and density indicated in the Rocky Mountain and Intermountain regions, providing the average height of the trees selected for site determination is equal to or exceeds the height of the site index 30 class but does not exceed the height of the site index 100 class at the age sampled. Figure 1 can be used if the CCF is 125 or less. In the Pacific Northwest region, site index can be estimated reliably only if the "site trees" are 50 or more years old.

Field Application of Site Index Curves

Step 1.--Determine average height and age of the stand. Select four or more dominant trees (site trees) and measure heights and ages in the conventional manner.[4] Average total age may be approximated from age at breast height by adding 9 years to the average age at breast height (fig. 1 and all tables are based on total age).

[4] *Chapman, Herman H. and Meyer, Walter H. Forest mensuration, Chap. 15, "The measurement of heights in standing trees," pp. 149-212 and Chap. 23, "The age of standing trees," pp. 318-323. New York: McGraw-Hill Book Co. 1949.*

Step 2.--Determine the CCF of the stand in which the "site trees" developed. Two alternative methods of obtaining CCF are suggested.

A. Estimate CCF from measurements of stand diameters at breast height.

1. Establish a density plot for each "site tree." It will be a fixed-radius plot centered on the "site tree" or close enough to the "site tree" to accurately estimate the stand density in which the "site tree" developed. Plot sizes are suggested in table 6. Plots for any group of four "site trees" should be the same size. Plots may overlap, so some trees may occur in more than one plot, and may, therefore, have to be tallied more than once.

2. Measure the diameters at breast height of all trees on the density plots, and record by 1-inch classes. It is not necessary to keep the data from the four density plots separate, but care must be exercised to locate the "site trees" and density plots that make up any sampling group in a part of the stand where density is representative, and where average spacing between trees and the average diameter of those trees are similar.

3. Multiply the number of trees in each diameter class by the MCA for that diameter class (MCA constants for each diameter class for lodgepole pine are given in column 2, table 7).

4. Sum the MCA values and convert to an acre basis. The resulting value is the CCF of the stand.

5. An example of the procedure outlined in step 2A, items 3 and 4, is shown in table 7 for a typical lodgepole pine stand.

B. Estimate CCF from measurements of basal area and average diameter.

1. Determine average basal area of the stand.
   a. Select the prism with the appropriate Basal Area Factor (BAF) for the density of the stand to be sampled.
   b. Count all trees that are "in" at each sample point. Each sample point should be sufficiently close to each "site tree" to permit a valid estimate of CCF around the "site tree."
   c. Total the trees counted at the sample points, and average to determine the average number for the plot.
   d. Multiply the average per plot by the appropriate BAF. The resulting value is basal area per acre.

2. Obtain an estimate of average diameter. There are many methods available for determining average diameter. The rule-of-thumb procedure described here is rapid and accurate for the purpose intended.
   a. Walk through the stand sampled, and select what appears to be a tree of average diameter.
   b. Lay out a transect line across the stand that passes close to each "site tree."
   c. Measure the first 10 trees along this line that appear to the observer to be of average diameter.
   d. Sum those diameters and obtain an arithmetical average. That value is the estimate of average diameter.

3. Determine the $BA/\overline{D}$ Factor by dividing the average basal area per acre by the average diameter.

4. Determine estimated CCF by substituting the $BA/\overline{D}$ Factor into the equation:

$$CCF = 50.58 + 5.25 (BA/\overline{D})$$

where

CCF = Crown Competition Factor
BA = Average basal area per acre
D = Average diameter

or obtain from figure 2.

Step 3.--Determine site index.

A. Select the appropriate height-age table, based on the CCF determined in Step 2 (if CCF is 125 or less, fig. 1 may be used in place of table 1).

B. Enter the appropriate height-age table with the average dominant height and age from Step 1. Determine site index in the conventional manner; interpolate where necessary.

Specifications for Stands and Site Trees

The following specifications, upon which figures 1 and 2 and tables 1 to 7 are based, are included to provide field users with a guide to the kinds of stands and site trees to be selected for sampling.

Stands:

1. Even-aged--not more than 20 years' spread in the age of dominant trees.
2. At least 30 years old, but not more than 200 years old. (At least 50 years old in Pacific Northwest.)
3. Apparent site the same throughout the stand. Site will be considered the same if all trees are growing on similar topography, slope, aspect, and soils.

Site Trees:

1. Located in an area in the stand where present density is uniform, and there have been no abrupt changes in past density.
2. Dominants that appear to have been dominant throughout their lives. (Dominants with a normal pattern of ring widths from pith to cambium to demonstrate that they have been free to grow throughout their lives, and no changes are likely to have occurred in their relative position in the crown canopy.
3. Reasonably free of dwarfmistletoe or other diseases or injuries that may reduce height growth.
4. Sound enough for ring counts.
5. Show no visible evidence of crown damage, or tops that are broken, forked, and so forth.

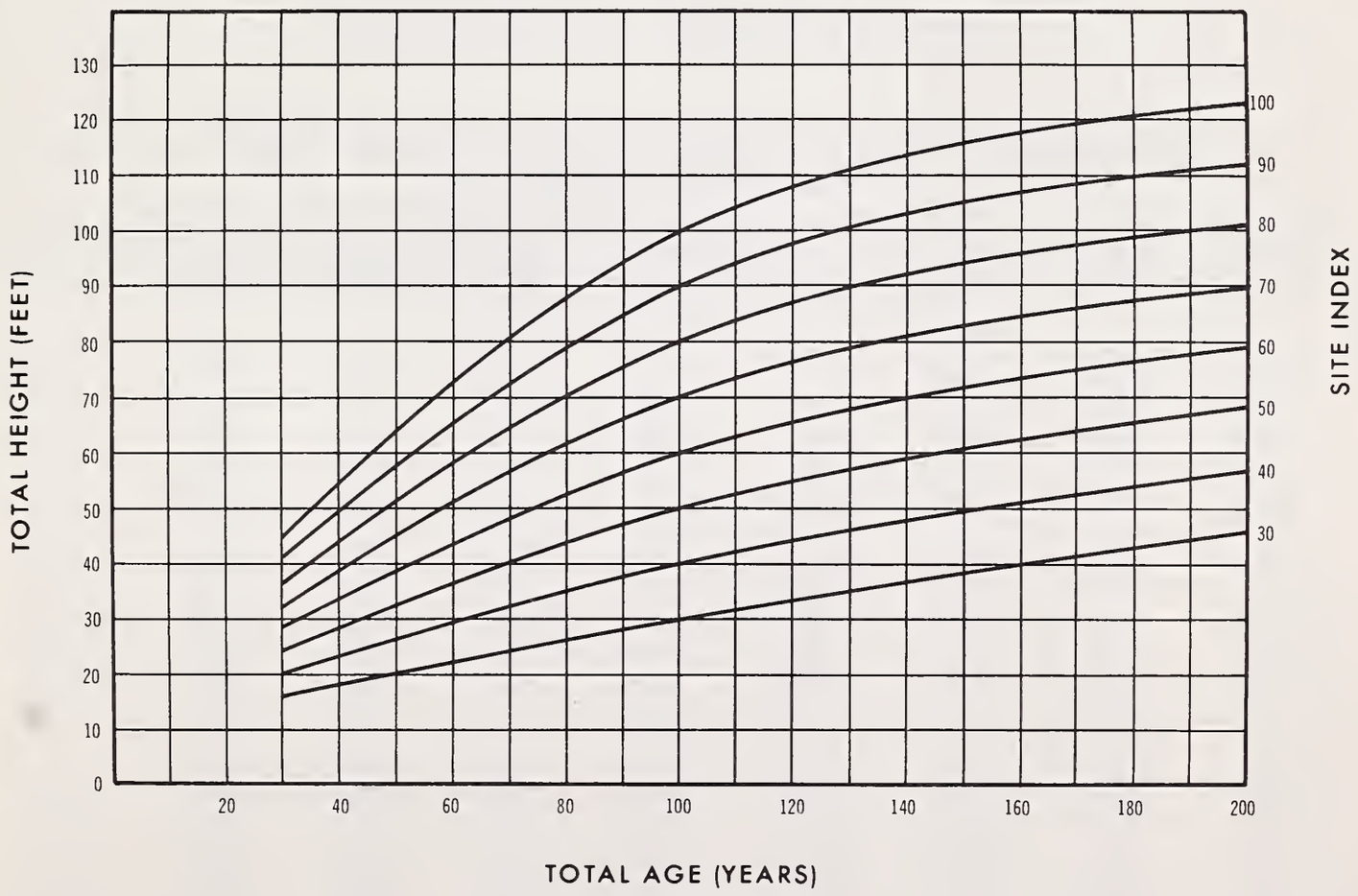

Figure 1.--Lodgepole pine site index curves for CCF 125 or less.

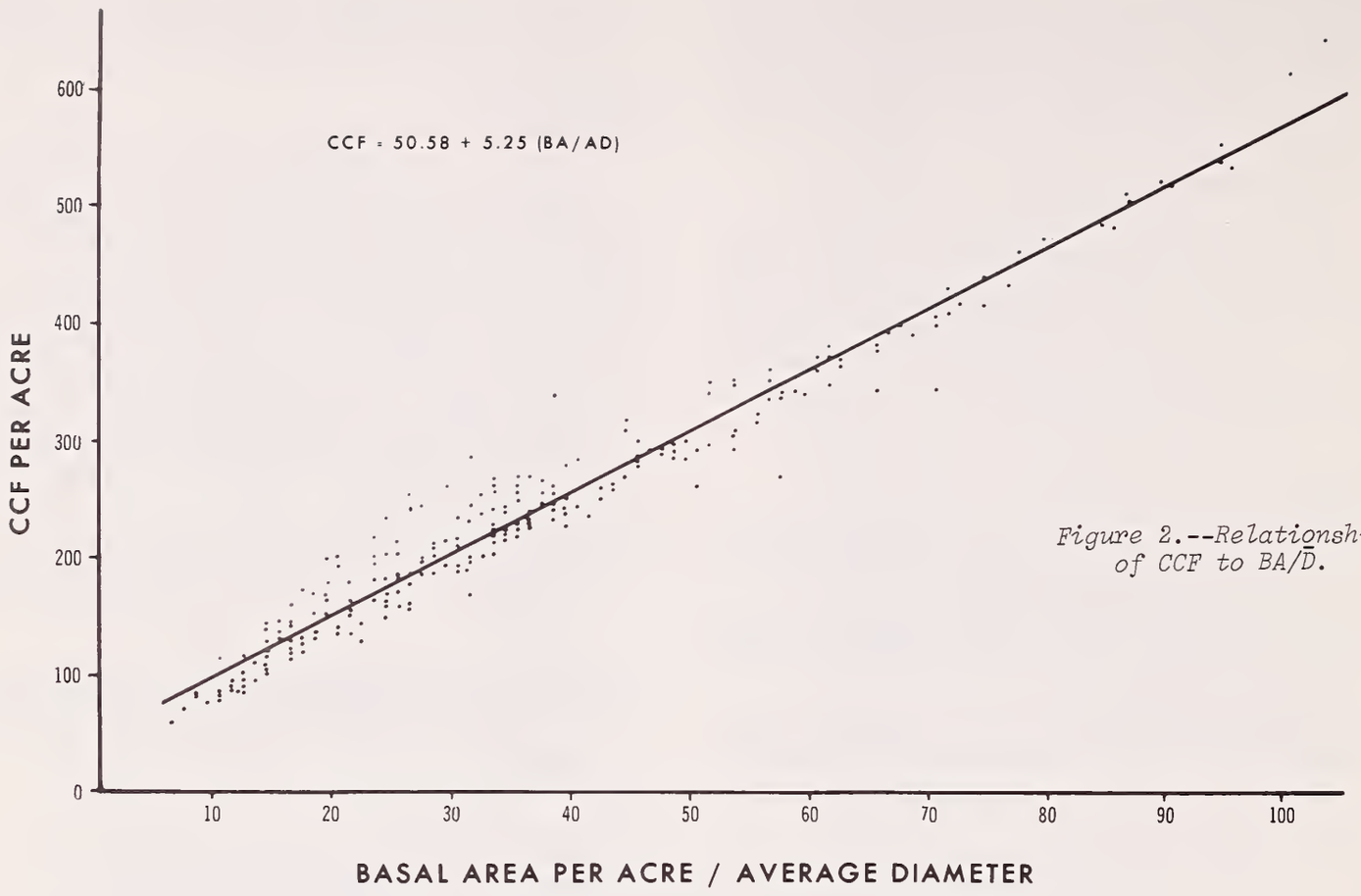

Figure 2.--Relationship of CCF to BA/D.

Table 1.--Heights of dominant trees at CCF levels of 125 or less for site index classes 30 to 100 by decadel ages 30 to 200 years

Total age (Years)	Site index class							
	30	40	50	60	70	80	90	100
	Height in feet							
30	16	20	24	28	32	36	40	45
40	18	23	28	34	39	44	49	55
50	20	26	32	39	45	51	58	64
60	22	29	36	44	51	58	65	72
70	24	32	40	48	56	64	72	80
80	26	35	44	52	61	70	79	88
90	28	37	47	56	66	75	85	94
100	30	40	50	60	70	80	90	100
110	32	42	52	63	73	84	94	104
120	34	44	55	66	76	87	98	108
130	35	46	57	68	79	90	101	111
140	37	48	59	70	81	92	103	114
150	39	50	61	72	83	94	105	116
160	40	51	62	73	84	96	107	118
170	42	53	64	75	86	97	108	119
180	43	54	65	76	87	99	110	120
190	45	56	67	78	89	100	111	122
200	46	57	68	79	90	101	112	123

Table 2. --Heights of dominant trees at CCF 200 for site index classes 30 to 100 by decadel ages 30 to 200 years

Total age (Years)	Site index class							
	30	40	50	60	70	80	90	100
	Height in feet							
30	14	18	21	25	28	32	35	38
40	16	21	25	30	35	39	44	48
50	18	24	29	35	41	46	52	58
60	20	27	33	40	47	53	60	66
70	22	30	37	45	52	59	67	74
80	24	32	41	49	57	65	73	81
90	26	35	44	53	62	70	79	88
100	28	37	47	56	66	75	84	94
110	30	40	49	59	69	79	88	98
120	32	42	52	62	72	82	92	102
130	33	44	54	64	74	85	95	105
140	35	45	56	66	77	87	98	108
150	37	47	58	68	79	89	99	110
160	38	49	59	70	80	91	101	112
170	40	50	61	71	82	92	103	113
180	41	52	62	73	83	94	104	114
190	43	53	64	74	84	95	105	116
200	44	54	65	75	86	96	106	117

Table 3. --Heights of dominant trees at CCF 300 for site index classes 30 to 100 by decadel ages 30 to 200 years

Total age (Years)	Site index class							
	30	40	50	60	70	80	90	100
	Height in feet							
30	12	14	17	20	22	25	28	30
40	14	17	21	25	29	33	36	40
50	16	21	25	30	35	40	45	50
60	18	24	29	35	41	47	52	58
70	20	26	33	40	46	53	59	66
80	22	29	36	44	51	59	66	73
90	24	32	40	48	55	64	72	80
100	26	34	43	51	60	69	77	86
110	27	36	45	54	63	72	81	90
120	29	38	48	57	66	75	85	94
130	31	40	50	59	69	78	88	97
140	33	42	52	61	71	81	90	100
150	34	44	54	63	73	83	92	102
160	36	46	56	65	75	84	94	103
170	38	47	57	66	76	86	95	105
180	39	49	58	68	77	87	97	106
190	40	50	59	69	79	88	98	108
200	41	51	61	70	80	90	99	109

Table 4. --Heights of dominant trees at CCF 400 for site index classes 30 to 100 by decadel heights 30 to 200 years

Total age (Years)	Site index class							
	30	40	50	60	70	80	90	100
	Height in feet							
30	9	11	13	15	17	18	20	22
40	11	14	17	20	23	26	29	32
50	13	17	21	25	29	33	37	41
60	15	20	25	30	35	40	45	50
70	17	23	29	35	40	46	52	58
80	19	26	32	39	45	52	59	65
90	21	28	36	43	50	57	64	72
100	23	31	39	46	54	62	70	77
110	25	33	41	49	57	66	74	82
120	27	35	44	52	60	69	77	86
130	28	37	46	54	63	72	80	89
140	30	39	48	56	65	74	83	92
150	32	41	49	58	67	76	85	94
160	34	42	51	60	69	78	86	95
170	35	44	53	61	70	79	88	97
180	36	45	54	63	72	81	89	98
190	38	47	55	64	73	82	91	99
200	39	48	57	65	74	83	92	101

Table 5. --Heights of dominant trees at CCF 500 for site index classes 30 to 100 by decadel heights 30 to 200 years

Total age (Years)	Site index class							
	30	40	50	60	70	80	90	100
	Height in feet							
30	7	8	9	10	11	12	13	14
40	9	11	13	15	17	20	22	24
50	11	14	17	20	24	27	30	33
60	13	17	21	25	29	33	38	42
70	15	20	25	30	35	40	45	50
80	17	23	28	34	40	45	51	57
90	19	25	32	38	44	51	57	63
100	21	28	35	42	48	55	62	69
110	23	30	37	44	52	59	66	74
120	24	32	40	47	55	62	70	78
130	26	34	42	49	57	65	73	81
140	28	36	44	52	59	67	75	83
150	29	37	45	53	61	69	77	85
160	31	39	47	55	63	71	79	87
170	33	41	49	57	65	73	81	89
180	34	42	50	58	66	74	82	90
190	35	43	51	59	67	75	83	91
200	36	44	52	60	68	76	84	92

Table 6. --Sizes of density plots to use for different maximum heights of site trees

Maximum height of site trees (Feet)	Plot radius	Plot size
	Feet	Acre
Unlimited	52.67	0.2
75	37.25	.1
53	26.33	.05
37	18.67	.025
24	11.75	.01
17	8.33	.005
12	5.92	.0025

Table 7. --MCA values for each diameter class, and sample computations of total MCA and CCF for a lodgepole pine stand

Diameter class	MCA[1] per tree	Number of trees	Total MCA	Sample computations
1	0.040			
2	.067			Plot size = 0.8 acre
3	.102			
4	.145			
5	.194			Total MCA = 159.6
6	.251			
7	.315	23	7.245	$CCF = \frac{\text{Total MCA}}{\text{Area in acres}}$
8	.387	41	15.867	
9	.466	37	17.242	
10	.552	47	25.944	$CCF = \frac{159.6}{0.8} = 199.5$
11	.645	50	32.250	
12	.746	30	22.380	
13	.854	24	20.496	
14	.969	12	11.628	
15	1.092	6	6.552	
			159.604	
16	1.222			
17	1.359			
18	1.504			
19	1.655			
20	1.814			

[1] Computed from equation, $MCA = 0.00365\,D^2 + 0.01676\,D + 0.01925$

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1966. Site indexes for lodgepole pine, with corrections for stand density: Instructions for field use. U. S. Forest Serv. Res. Paper RM-24, 7 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 80521.

Figures and tables are presented for estimating corrected site index of lodgepole pine. Site indexes are adjusted for stand density on the basis of data from Colorado, Wyoming, Utah, Idaho, Montana, and eastern Washington and Oregon. Methodology used to develop the curves will be in a subsequent paper.

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